LAKE OKEECHOBEE DRAINAGE BASIN

SUMMARY

MAP

Phosphorus Loading and Rainfall Trends

Historic and monthly data for rainfall, flows and phosphorus loads to Lake Okeechobee are presented for 1999 (**Figure 1**) and for 2000 (**Figure 2**). In both figures, monthly values for each of these parameters are depicted as bars. Solid lines represent monthly means based on the previous 20-years of data. A 20-year period was chosen because it provided a quality-assured data set for water quality and covered both drought and wet conditions. The dashed and dotted lines in each figure depict the 95 percent confidence interval about this 20-year mean. In other words, a 95 percent chance exists that a value will fall within that confidence level (**Figures 1** and **2**).

Monthly rainfall shown in each of the figures is presented as area-weighted averages from a network of meteorological stations in the Upper Kissimmee, Lower Kissimmee and Lake Okeechobee basins. Flows are compiled from directly measured data at 26 monitoring stations that discharge into the lake. Phosphorus loads to the lake were calculated by multiplying concentration data from those 26 monitoring stations and their respective flow data.

The effects of the Shared Adversity Plan (Resolution No. 00-31) on Lake Okeechobee is described in the October 2000 Issue of the *Environmental Conditions Update* (SFWMD, 2000).

Higher phosphorus loads have typically occurred during wetter months (June through October), while lower loads occur during drier months of the year (**Figures 1** and **2**). In 1999, the period from June through October (excluding July) exhibited higher rainfall than the 20-year average for these months. As a result, flows and phosphorus loads for these five months were greater than their 20-year means (**Figure 1**). Flows and loads for all the months of 2000 were below their 20-year averages (**Figure 2**).

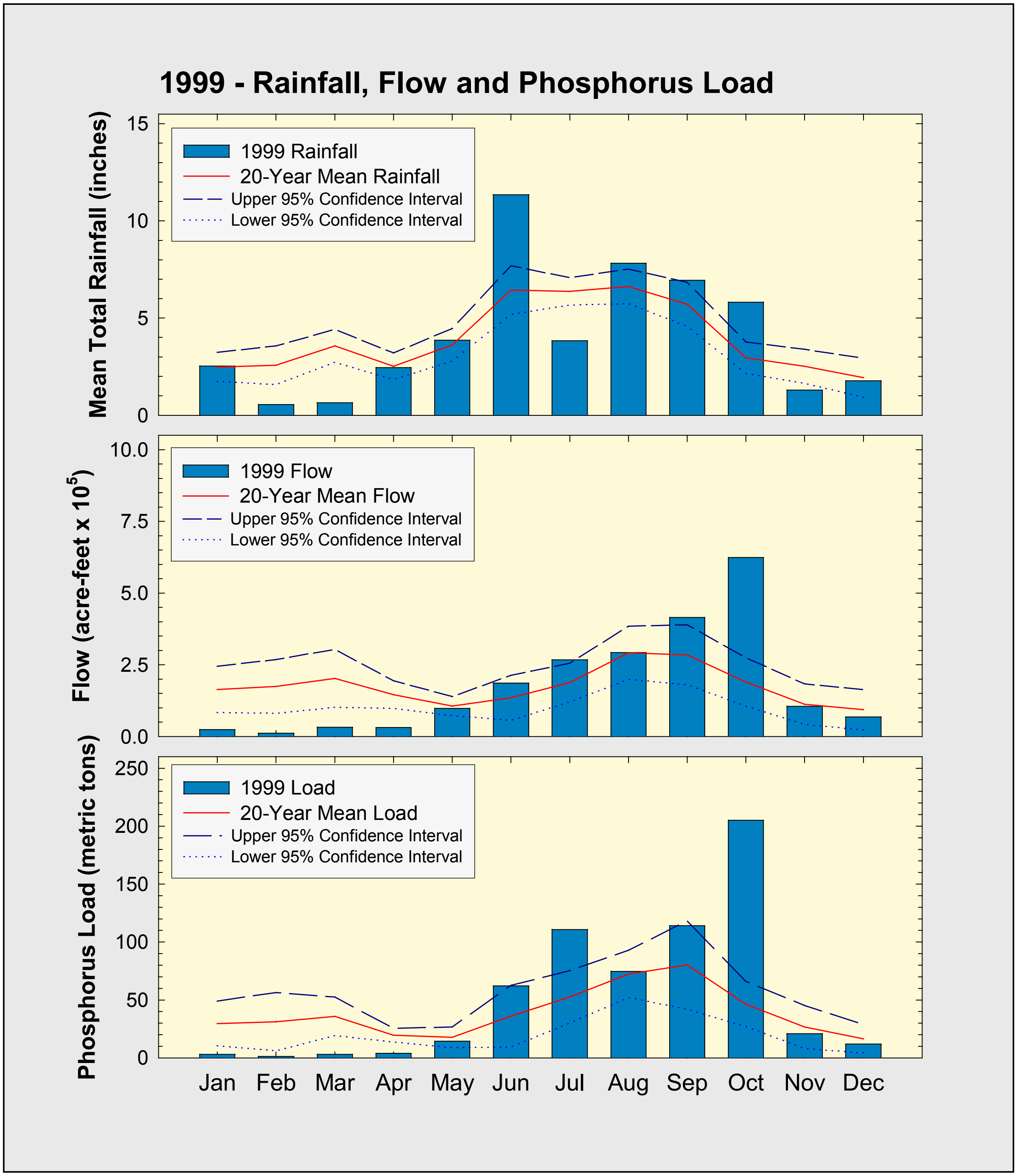


Figure 1. Monthly total phosphorus rainfall, flow and loads for Lake Okeechobee during 1999.

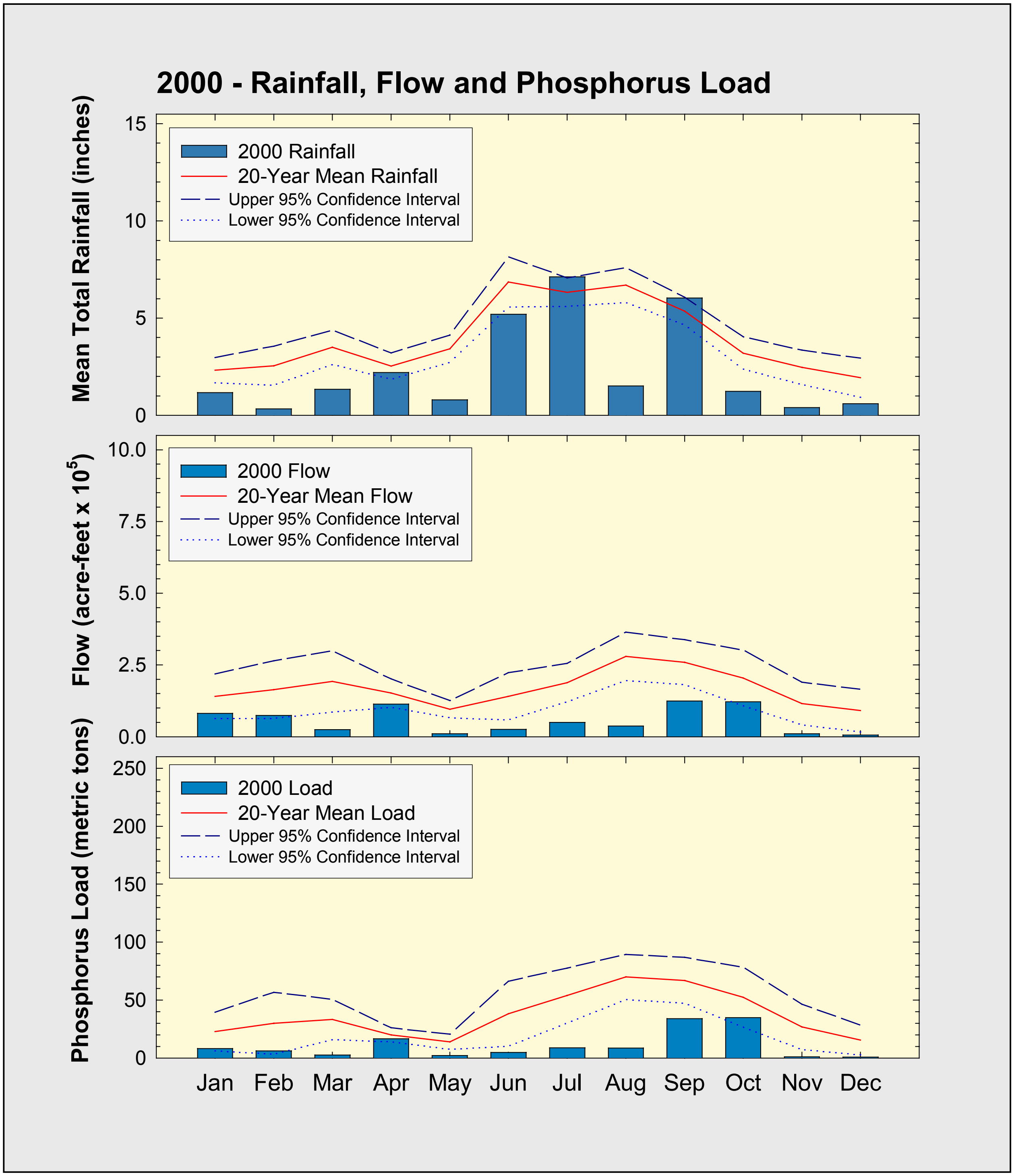


Figure 2. Monthly total phosphorus rainfall, flow and loads for Lake Okeechobee during 2000.

Major climatic disturbances (such as El Niño, tropical storms and hurricanes) can alter the seasonal distribution of phosphorus to Lake Okeechobee. During October 1999, scheduled releases of water from Lake Kissimmee combined with Hurricane Irene contributed to the 205 metric tons of phosphorus released to Lake Okeechobee for that month (**Figure 1**).

During the fourth quarter of 2000, monthly rainfall amounts for October, November and December 2000 were 1.2, 0.4 and 0.6 inches, respectively, across the Lake Okeechobee Basin (**Figure 2**) with November being one of the driest in 30 years. A poorly organized subtropical disturbance passed through south Florida in early October with most of the rainfall associated with this system falling south of the lake. Most of the October rainfall recorded in the Lake Okeechobee Basin is attributed to this disturbance. In 1999, the rainfall amounts for these corresponding months were 5.8, 1.3, and 1.8 inches (**Figure 1**) or approximately 7 inches more than in the fourth quarter of 2000. Monthly rainfall amounts recorded in October through December 2000 were below the 95 percent confidence interval for these months, based on the previous 20 years of data (**Figure 2**).

Lower average rainfall during the fourth quarter resulted in lower flows and phosphorus loads to the lake (**Figure 2**). Phosphorus loads to Lake Okeechobee in October, November and December 2000 were 35, 1.1 and 0.9 metric tons, respectively, compared to 205, 21 and 12 metric tons during the corresponding months in 1999.

Approximately 44 percent of the phosphorus load entering the lake in the fourth quarter of 2000 was from backpumping at S2 and S3 from October 4-6, 2000 and from periodic releases from the Loxahatchee National Wildlife Refuge through Culvert 10A. In addition, approximately 8 percent of the total load entered Lake Okeechobee through S308 as a result of higher water elevations in the C-44 canal than in the lake. In contrast, the phosphorus load from the Kissimmee River through S65E accounted for less than five percent of the total load to the lake during the fourth quarter. Overall, the phosphorus load for the fourth quarter of 2000 was approximately 2.5 times lower than the 20-year average for the same period (**Figure 2**).

Phosphorus Concentrations for Tributaries and Basins

A phosphorus concentration target for each basin in the Lake Okeechobee Watershed was established under the 1989 Interim Surface Water Improvement and Management (SWIM) Plan. This target was incorporated to ensure a reduction in phosphorus loads to Lake Okeechobee. Under this SWIM Plan, the phosphorus concentration from each basin must either be below 180 parts-per-billion (ppb) or at the 1989-discharge concentration, whichever is less.

The Lower Kissimmee River, S154, Fisheating Creek and Taylor Creek/Nubbin Slough Basins are generally major contributors of phosphorus load to the lake. Flow-weighted mean concentrations of total phosphorus from these four basins were used to calculate the 12-month moving average concentrations shown in **Figure 3**.

Since May 1991, the phosphorus concentrations for the Kissimmee River Basin have consistently been at or below the target concentration of 180-ppb (**Figure 3a**). Phosphorus concentrations from the Kissimmee decreased from 106 ppb in October 2000 to 93 ppb in December 2000.

During the first five months of 2000, phosphorus concentrations from the S-154 Basin were about 850 ppb. Phosphorus concentrations decreased to 440 ppb in November 2000 (**Figure 3a**). By December, the 12-month moving average total phosphorus concentration increased to 510 ppb.

The moving average phosphorus concentrations in Fisheating Creek have varied above and below the 180-ppb target level. From October 1996 through September 1999, the phosphorus concentrations in the creek were consistently above the target (**Figure 3b**). From October 1999 through September 2000, phosphorus concentrations remained below the target limit. However, phosphorus concentrations increased during the fourth quarter, reaching 310 ppb by December 2000.

A sharp increase in phosphorus concentrations from about 650 ppb to over 870 ppb was observed for the Taylor Creek/Nubbin Slough Basin from September 1999 through September 2000 (**Figure 3b**). The 12-month moving average total phosphorus concentrations were approximately 250 ppb lower in October and November of 2000 compared to September 2000. By December 2000, the phosphorus concentration increased slightly to 620 ppb.

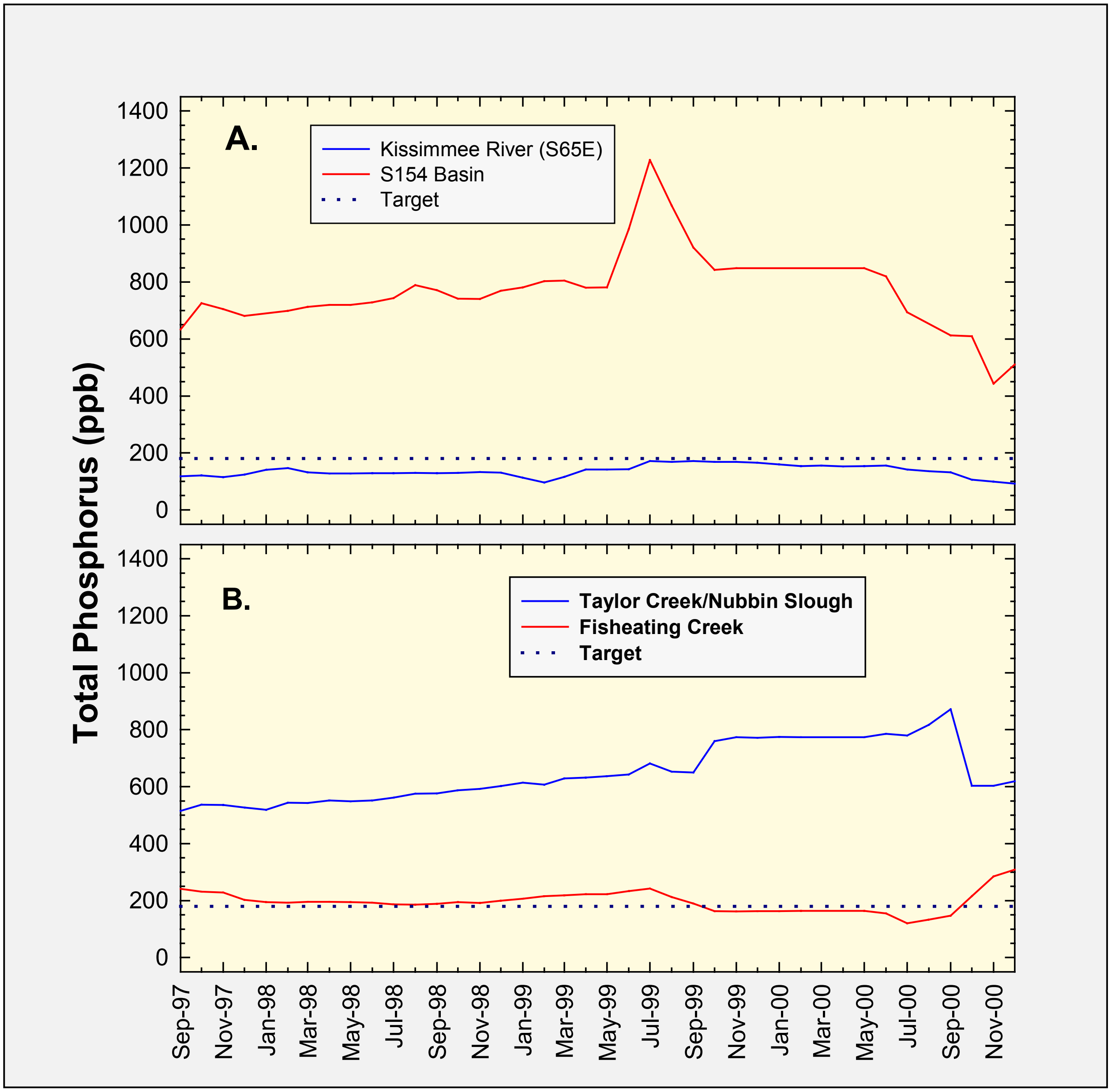


Figure 3. Twelve-month moving flow-weighted mean total phosphorus concentrations for: a. Kissimmee River and S154 Basins and b. Taylor Creek/ Nubbin Slough and Fisheating Creek. The four basins/tributaries drain into Lake Okeechobee.

Long-Term Analysis

A long-term analysis of phosphorus loads is provided as a 5-year moving average calculated at the end of each calendar year. These averages are calculated for actual and target phosphorus loads. The actual load consists of the inflow from tributaries to the lake each year plus an assumed contribution from atmospheric deposition of 64.4 metric tons per year (**Figure 4a**). The target load is calculated using the modified Vollenweieder model. The difference between the target and actual loads is referred to as the ***over-target load*** and is presented in **Figure 4b**. The actual, target, over-target and 5-year moving average loads are summarized in **Table 2** for the period from 1973 through 2000.

Over the past decade, several programs have been implemented to reduce phosphorus loads to Lake Okeechobee. These programs include best management practices (BMPs), dairy buy-outs, regulatory programs for non-dairy uses of land, and minimizing limited backpumping to the lake from the Everglades Agricultural Area (EAA). It is apparent that these programs by themselves will not be sufficient to achieve the required in-lake concentration and associated load reduction and, therefore, must be supplemented with other load reduction measures. The Lake Okeechobee Water Retention/ Phosphorus Removal Critical Restoration Project has been developed to increase regional water storage north of Lake Okeechobee by on-site wetland restoration and water retention, with a secondary benefit of reducing phosphorus in surface runoff. Currently, 12 potential sites have been identified. Two are for proposed stormwater treatment (attenuation) facilities, which the U.S. Army Corps of Engineers will design and construct. At the other 10 sites, the District has proposed to design and construct modifications to improve stormwater retention, restore wetlands and improve the quality of discharged water. These proposed project sites are located throughout the northern Lake Okeechobee watershed, in the lower Kissimmee River Basins (S-65D and S-65E), S-154, and the Taylor Creek-Nubbin Slough Basins (S-191).

In-Lake Total Phosphorus Concentrations

Lake Okeechobee has a long history of excessive phosphorus loading, which has resulted in major changes in the ecosystem, including an increased frequency of algal blooms, predominantly blue-green algae, and the accumulation of over 30,000 metric tons of phosphorus in the lake sediments. From the early 1970s to the 1990s, total phosphorus concentrations in the lake's water column increased from below 50 ppb to over 100 ppb. Present high total phosphorous concentrations are a function of high external loads and frequent resuspension of phosphorous-rich mud bottom sediments caused by wind. The South Florida Water Management District and other agencies have initiated an aggressive program to reduce external phosphorus loads to the lake and are conducting a feasibility study to determine the ecological, engineering and economic implications of reducing the internal phosphorous load from the lake's sediments.

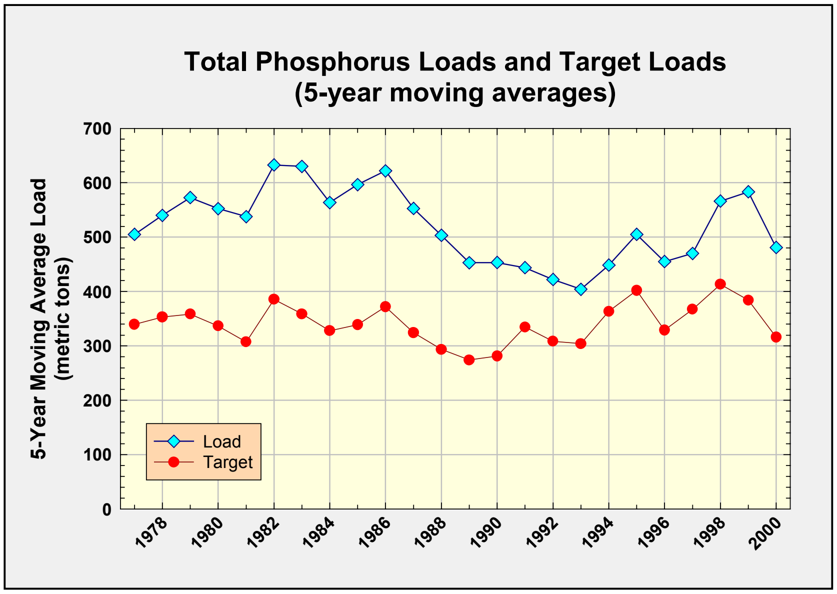


Figure 4a. Comparison of the actual load o the target load. Data are 5-year moving averages.

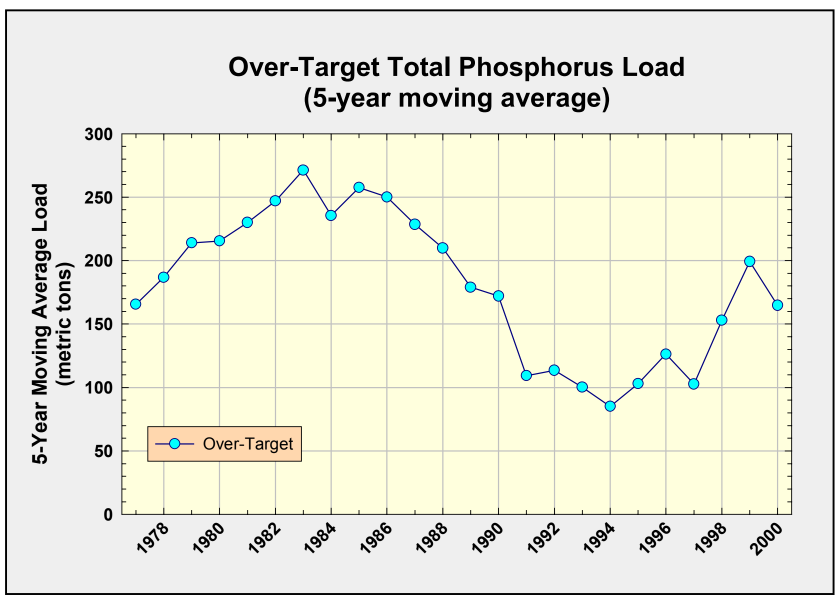


Figure 4b. The 5-year moving average of over-target loading to Lake Okeechobee. This data is the difference between the actual load and the target load depicted in **Figure 4**a.

Table 2. Historic Total Phosphorus Loading Data

Year	Actual Load (metric ton)	Target Load (metric ton)	Annual Over Target (metric ton)	Long-Term Over-Target (5-yr moving average)
1973	499	476	22	
1974	802	414	389	
1975	361	266	95	
1976	467	285	182	
1977	397	257	140	166
1978	672	544	128	187
1979	966	441	524	214
1980	260	157	102	215
1981	393	138	255	230
1982	873	648	225	247
1983	659	409	250	271
1984	634	288	345	235
1985	424	211	213	258
1986	521	303	217	250
1987	526	410	117	228
1988	413	256	157	210
1989	382	191	191	179
1990	425	247	178	172
1991	474	570	-96	109
1992	418	280	137	114
1993	323	232	90	100
1994	604	488	116	85
1995	707	440	267	103
1996	225	205	20	126
1997	492	472	20	103
1998	804	462	342	153
1999	689	342	347	199
2000	194	100	94	165

In order to assess the seasonal and spatial variations in phosphorus concentrations in the lake resulting from inputs as well as internal cycling, distribution plots of open-water total phosphorus concentrations are presented in **Figures 5a** through **5c**.

The arithmetic mean concentration of total phosphorus was 111, 55 and 148 ppb for October, November and December, respectively. By comparison, total phosphorus concentrations for the corresponding months in 1999 were 94, 190 and 184 ppb, respectively. During the fourth quarter, total phosphorus concentrations ranged from 13 to 363 ppb.

The contour plot shown in **Figure 5a** depicts total phosphorus concentrations for October 2000. Approximately 36 percent of the total phosphorus concentrations measured for this month were less than 100 ppb (**Figure 5a**). Total phosphorus concentrations greater than 100 ppb extended from the eastern shore to the central portion of the lake. The higher phosphorus concentrations measured in the eastern portion of the lake may reflect the effects of backflow of water from the C-44 canal through the S308 structure and inflow through Culvert 10A. More importantly, wind from the subtropical disturbance in the first part of October may have resuspended the fine-grained sediments in the lake resulting in the higher phosphorus concentrations observed for the month.

By November 2000, total phosphorus concentrations decreased throughout the lake. Approximately 75 percent of phosphorus concentrations measured in the lake were below 100 ppb (**Figure 5b**). Fisheating Bay, located in the western portion of Lake Okeechobee, as well as the near shore areas in the southwestern portion of the lake had total phosphorus concentrations lower than 40 ppb. Overall, the lower phosphorus concentrations measured in November 2000 may reflect the combined influence of two phenomena. First, low amounts of phosphorus from the watershed entered the lake due to reduced rainfall. Second, the lowered lake levels, as well as absence of windy conditions, allowed for suspended material to settle quickly.

Phosphorus concentrations in the lake increased in December with 70 percent of the lake's surface water having levels greater 100 ppb. Concentrations greater than 200 ppb extended from the central portion of the lake to the northeastern shores (**Figure 5c**). The lowest loads of phosphorus to Lake Okeechobee in the fourth quarter occurred in December 2000. Therefore, the increased phosphorus concentrations for the month are probably not a result of inflows. A more probable source for the increased phosphorus may be resuspension of the phosphorus-rich, fine-grained sediments. Wind action generated by late fall fronts probably resuspended these sediments and increased the overall phosphorus content of the lake.

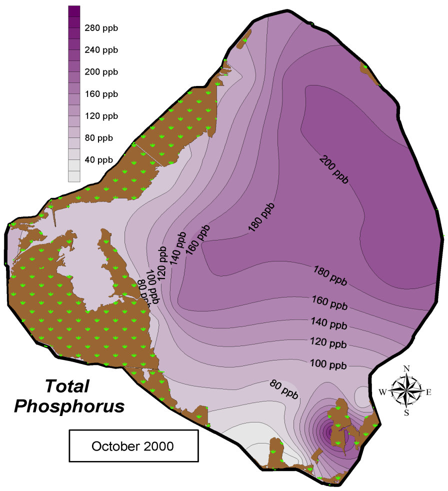


Figure 5a.
Total phosphorus concentrations for open water monitoring sites in Lake Okeechobee, October 2000.

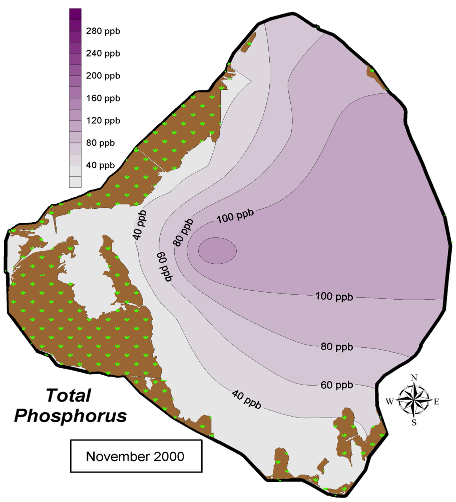
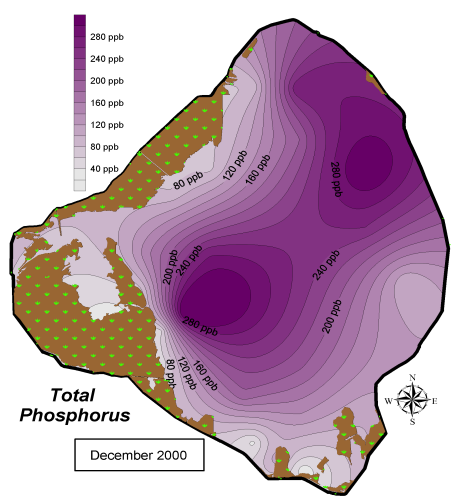


Figure 5b.
Total phosphorus concentrations for open water monitoring sites in Lake Okeechobee, in the first half of November 2000.

Figure 5c.
Total phosphorus concentrations for open water monitoring sites in Lake Okeechobee, in the second half of December 2000.



Light Penetration

Secchi depth is a measure of how deep light penetrates the water column. The Secchi depth is measured by lowering a 30-cm diameter white disk through the water column until it is just visible. At the Secchi depth, solar light penetrating the water is reflected off the surface of the disk in a quantity sufficient to come back through the water and reach the observer's eye. The amount and composition of suspended material along with the presence of dissolved colored substances in the water column affect Secchi depth. When either of these two variables is high, light will not penetrate deeply into the water column (*i.e.*, Secchi depth decreases).

The transmission of light in lakes and other bodies of water is extremely important because solar radiation is the primary source of energy for photosynthetic organisms such as algae and aquatic plants. An increase in light penetration can cause increased photosynthetic activity, resulting in higher primary productivity if nutrients are not limiting.

Contour plots depicting Secchi depths in Lake Okeechobee during the fourth quarter corresponded to the contours plots for phosphorus (**Figures 6a** to **6c**). The average Secchi depths for October , November and December 2000 were 0.3, 0.7 and 0.3 meters, respectively.

Light penetration in Lake Okeechobee extended to a maximum depth of 0.6 meters in October 2000 (**Figure 6a**). However, approximately 83 percent of the lake had light penetrating to a depth less than 0.4 meters. Secchi depths lower than 0.2 meters extended from the central through northeastern portions of the lake.

By November, light penetration in Lake Okeechobee improved. Approximately 58 percent of the lake had Secchi depths greater than 0.4 meters. In the southwestern region of the lake, light penetration extended to a maximum depth of 1.2 meters (**Figure 6b**).

Approximately 88 percent of the lake in December 2000 had light penetrating to less than 0.4 meters (**Figure 6c**). Secchi depths less than 0.2 meters covered approximately 51 percent of the lake and stretched from the south-central portion to the eastern and northeastern shores.

An inverse relationship between Secchi depth and total phosphorous was also observed during the fourth quarter of 2000. In other words, higher total phosphorus concentrations were observed in regions having lower Secchi depths. Average Secchi depths measured during the fourth quarter of 2000 improved by approximately 0.2 meters compared to the corresponding period in 1999.

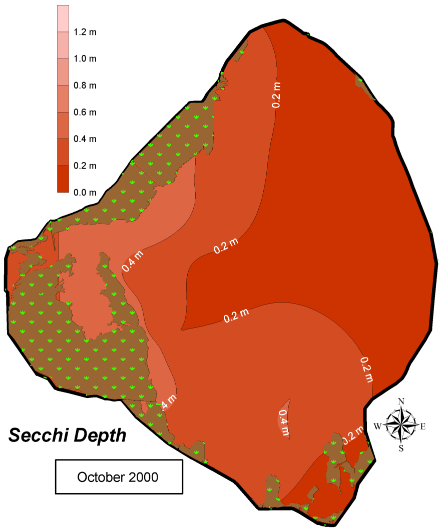


Figure 6a. Depth of light penetration (Secchi depth) measured in meters for Lake Okeechobee, first half of October 2000.

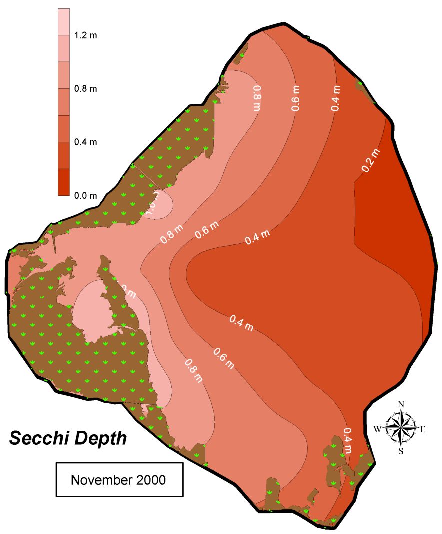


Figure 6b. Depth of light penetration (Secchi depth) measured in meters for Lake Okeechobee, first half of November 2000.

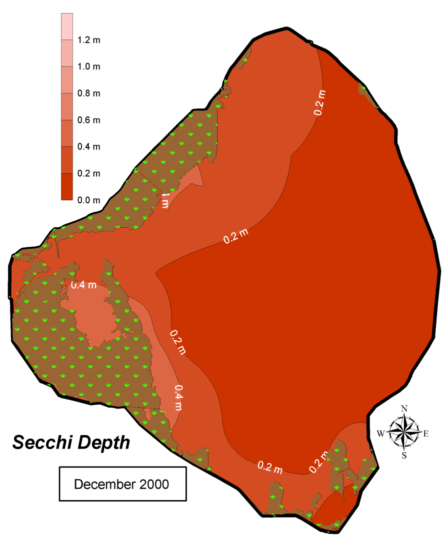


Figure 6c. Depth of light penetration (Secchi depth) measured in meters for Lake Okeechobee, second half of December

Chlorophyll *a* Concentrations

Chlorophyll *a* is a green pigment present in terrestrial and aquatic plants, including algae. This pigment functions to absorb visible light. The energy associated with the absorbed light is used to drive photosynthesis. Chlorophyll *a* concentrations are an indicator of the amount of living plant (or algal) material in a water body.

Naturally occurring algal populations present in Lake Okeechobee will form blooms under certain weather and water quality conditions.

Algal blooms are dense concentrations of algae over large areas of a water body. Blooms might be composed of undesirable species that are harmful to other aquatic life, possibly form nuisance scums on the water surface and create taste and odor in the drinking water supply. If algal populations are large enough, they can also reduce oxygen levels in the water column during algal die-off resulting in invertebrate and fish kills.

Severe bloom conditions generally occur when chlorophyll *a* concentrations exceed 60 ppb. Concentrations between 40 and 60 ppb are indicative of moderate bloom conditions. The occurrence and effects of these bloom conditions on the lake depend on a variety of factors. Persistence of bloom conditions over large areas may indicate increased nutrient concentrations.

Lake-wide chlorophyll *a* distributions for monitoring events during the fourth quarter in 2000 are presented in **Figures 7a** through **7c**. Chlorophyll *a* levels averaged 28.1 ppb in October, 10.63 ppb in November and 19.7 ppb in December. These average chlorophyll *a* levels were comparable to those reported for the same period in 1999.

In October, a moderate bloom condition was observed extending from Fisheating Bay on the western side of the lake (**Figure 7a**). Another moderate bloom was observed along the northwestern shores of the lake. These two bloom conditions covered approximately 23 percent of the lake’s surface water.

No bloom conditions were observed during November 2000 (**Figure 7b**). Chlorophyll *a* concentrations ranged from 3.1 to 31 ppb.

Although chlorophyll *a* concentrations increased by the December monitoring event, less than 1 percent of the lake exhibited bloom conditions (**Figure 7c**). A small moderate bloom was observed at the littoral shelf in the south. The highest chlorophyll *a* level recorded here was 49 ppb.

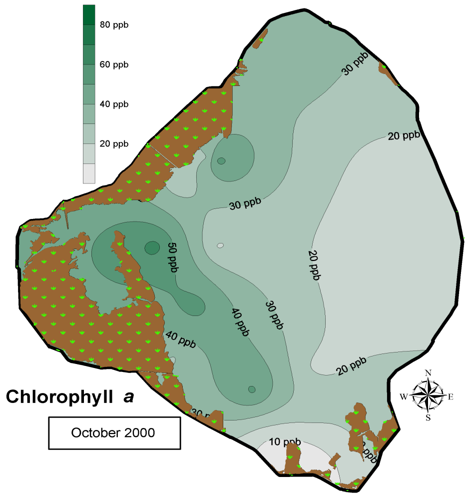


Figure 7a. Chlorophyll *a* levels in Lake Okeechobee, October 2000

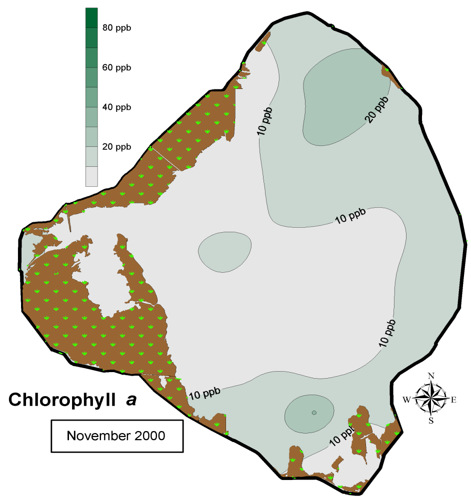


Figure 7b. Chlorophyll *a* levels in Lake Okeechobee, November 2000

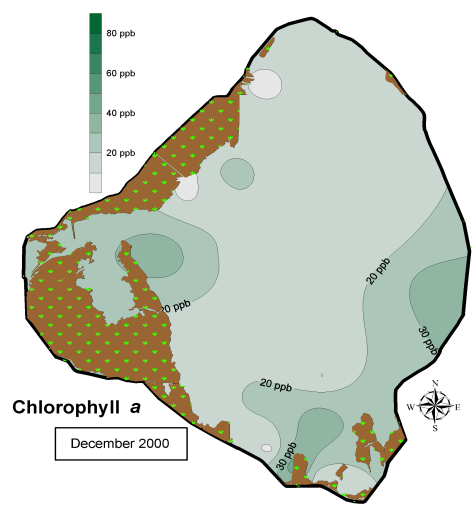


Figure 7c. Chlorophyll *a* levels in Lake Okeechobee, December 2000